

WILEY



The Ecology of Future International Politics

Author(s): Bruce M. Russett

Source: *International Studies Quarterly*, Vol. 11, No. 1 (Mar., 1967), pp. 12-31

Published by: [Wiley](#) on behalf of [The International Studies Association](#)

Stable URL: <http://www.jstor.org/stable/3013988>

Accessed: 17/06/2014 17:51

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at
<http://www.jstor.org/page/info/about/policies/terms.jsp>

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.



Wiley and The International Studies Association are collaborating with JSTOR to digitize, preserve and extend access to *International Studies Quarterly*.

<http://www.jstor.org>

*The Ecology of Future International Politics**

BRUCE M. RUSSETT

YALE UNIVERSITY

The range and probability of future outcomes

The prediction of future world events is frequently an exercise in political sociology. Or perhaps more accurately, it is a problem in political ecology, one concerned with the relationship between the political system and its social and physical environment.

A statement that nothing will change over the next few decades would hardly be credible, and anyway it would be boring. On the other hand, to quote one of my favorite books on prediction, "If a man predicts large but not very large changes, the public will regard him as a man of imagination; but if he predicts extremely large changes, his audience will replace imagination by phantasy."¹ I would like, in this paper, to avoid both extremes. In any case, my recent menus have offered neither sheep livers nor chicken entrails, so I am unable to engage in prophecy. I will not attempt to foretell a specific event on a specific occasion, nor to paint a detailed picture of a particular political future. But I am a restrained believer in the outlook aptly labelled by Charles Burton Marshall as "the limits of foreign policy."² Without getting into the determinist-free will debate—which in the still youthful state of our sciences is

* An earlier version of this paper was given as an address to the Annual Meeting of the American Sociological Association at Miami Beach, August 29, 1966. Marc Pilisuk, J. David Singer, Harold Sprout, and Guy E. Swanson offered valuable comments. I wrote the paper while Visiting Research Political Scientist at the Mental Health Research Institute, University of Michigan, and am grateful for its stimulating environment.

¹ H. Thiel, *Economic Forecasts and Policy* (Amsterdam: North Holland, 2nd edition, 1961), p. 156.

² Charles Burton Marshall, *The Limits of Foreign Policy* (New York: Henry Holt, 1954).

largely irrelevant anyway—we can, I think, agree generally with the idea that political prediction is best concerned with the future state of the *milieu* within which decisions have to be made. In this context we are interested in *negative* prediction—we aspire to narrow the range of possibilities, to eliminate some events as unlikely, and to produce a range of outcomes within which future developments will lie.³

In effect, we want to do what we do as scientists when generalizing from our samples to larger populations; we want to make a prediction that states both a *range* of possibilities—the confidence interval—and the probability, or *significance level*, that we attach to the likelihood that the true value will fall within that range. If we give as a “best guess” some point within that interval, we recognize that it is really only shorthand for a much more complicated statement. I think this is true whether we are making explicitly quantitative statements, such as the number of people who would be killed in a nuclear war, or whether we are talking about apparently discrete events, such as whether or not “war” will occur. We may simplify our analytical models to talk about war *vs.* peace, but we know that there are many shades and varieties of each, and that in *many* respects the “war” we refer to is less a step-level jump from previous states than the mode of a distributional curve. We have learned this well from our recent experiences with civil unrest and insurgency. All of us know too about the problem of subjective probabilities and the inappropriateness of assigning a probability to a unique event; when we make a prediction that is not based on a sample from a known universe we are beyond the limits within which the assignment of precise probability levels is permissible. Yet without some such effort, however crude and subjective, the analysis is incomplete and misleading.

³ See Harold and Margaret Sprout, *The Ecological Perspective on Human Affairs* (Princeton, N.J.: Princeton University Press, 1965), pp. 180, 199. See also Thiel, *op. cit.*, ch. 1; and Nicholas Rescher, “Discrete State Systems, Markov Chains, and Problems in the Theory of Scientific Explanation and Prediction,” *Philosophy of Science*, 30 (1963), pp. 325-45; and, for a similar if less rigorous and overly cautious statement, Saul Friedlander, “Forecasting in International Relations,” in Bertrand de Jouvenel, ed., *Futuribles: Studies in Conjecture*, II (Geneva: Droz, 1965), p. 99. On the difficulties of predicting particular events, relevant comments include those by Wilbert E. Moore, *Social Change* (Englewood Cliffs, N.J.: Prentice-Hall, 1963), pp. 3-4; and Kenneth E. Boulding, “Expecting the Unexpected: The Uncertain Future of Knowledge,” in Edgar Morphet and Charles Ryan, eds., *Conference on Designing Education for the Future*, Denver, Colo., July 1966.

Suppose that we have a prediction that a particular kind of war promises to bring death to between 5 and 25 million Americans. The President of the United States must decide in a crisis whether that is a price the country should pay in order to defend Western Europe. However he chooses to phrase his question, he must ask further, "What are the *probabilities* that the casualty level will actually fall within this range?" Presumably his decision would be quite different if his advisor could say he was *very* confident (say, a 99 per cent probability) that casualties would not exceed the upper limit of this range, than if he thought there was as much as one chance in three that the upper limit might be exceeded. Without both elements, the apparent precision of a quantitative confidence interval smacks of scientism, and the consumer would be better off with a vague but honest, "I am rather confident" or "only moderately confident" that the actual casualty level will be within the range, than he would be with a statement that gives no inkling whatever of the probability the forecaster may have had in mind.⁴

But this is not meant to be a treatise on the statistics of deadly quarrels, nor on scientific method either. I now want to consider another kind of prediction—how one can examine smooth changes in order to identify more or less discrete ones, in effect to anticipate system change. I will, however, stay within the framework outlined at the beginning—we will not be trying to predict particular events, but changes in the social and technological environment that will produce political and further social changes of one sort or another, changes that will lead to quite different social and political systems and present to future decision-makers the opportunity, and usually the necessity, for choice.

Rigor, information, and imagination

Imagination is often useful, and sometimes essential, for accurate prediction. Yet there have *always* been some men who had imagination, and only in recent decades has prediction been dramatically improved in many areas. We now predict economic conditions, elections, demographic trends, with imperfect but notably better success than we used to. This success is dependent less upon flights of imagination than upon a mixture of information and rigor.

Formal rigor means eliminating contradictions, preventing ob-

⁴ I am thinking, of course, of Herman Kahn, *On Thermonuclear War* (Princeton, N.J.: Princeton University Press, 1960), though he is by no means the only offender, and his use of ranges was a notable improvement over all previous efforts in this area.

security, and avoiding leaps in logic. Perhaps even more important, the rigorous formulation of a problem very often identifies a trend that wouldn't be apparent from mere intuition or imaginative speculation. Deductive reasoning has been the great strength of traditional sociology, and, sometimes without the sociologists' rigor, of traditional political science too. Now, rigor is frequently supplied by mathematics or symbolic logic. Despite the occasional abuse of mathematics and symbols, these tools have a remarkable ability to show up relationships that would otherwise escape notice. A primary reason for the greater success of economists and demographers in predicting future developments has undoubtedly been their increased use of rigorous—that is, mathematical—theories.⁵

One of the most striking and popular applications has long been the projection of exponential growth rates from the past into the future. An exponential growth rate is of course simply like compound interest, where a quantity regularly increases by some *proportion* of itself, rather than by a standard absolute *amount*. Hence, when graphed, the pattern is of a rising and ever-steeper curve, rather than an upwardly sloping straight line. It is in fact one of the simplest of all models, known in the trade as a first-order system.⁶ Yet for limited periods of time, and under stable conditions, it is an extraordinarily useful model. Probably the most familiar example is that for the population explosion, where the world's current annual rate of population increase, about two per cent or a doubling every 35 years, is projected forward and the density of the land areas of the globe is projected to a level exceeding present-day Hong Kong's by the year 2200. Similar growth rates have been publicized by Derek Price for the expansion of science. The household phrase about "almost 90 per cent of all scientists who ever lived are alive today" comes directly from his work.⁷ As we go on I shall identify some other social phenomena that have grown at exponential, and often remarkably steady, rates for years or decades.

The fact that so many processes have exhibited exponential

⁵ Obviously there are plenty of examples where economists and demographers have fallen on their faces in prediction, though not so grossly in recent years as in the earlier stages of their sciences' development. In general, it is fairer to compare present social science's predictive power with that of its predecessors than to disparage it by comparing it with its natural science contemporaries. See Bernard Barber, *Science and the Social Order* (Glencoe, Ill.: Free Press, 1952) p. 243.

⁶ Boulding, *op. cit.*

⁷ Derek J. de Sola Price, *Science Since Babylon* (New Haven, Connecticut: Yale University Press, 1961), ch. 5. See also his *Little Science, Big Science* (New York: Columbia University Press, 1963).

growth rates is no accident, nor is the rate itself merely a coincidence or a statistical construct forced on the unwilling data. Science feeds upon itself, with some scientific progress making possible the cumulation of further progress. The growth of *science* has made possible many *technological* changes, as of course the demand for these improvements has provided the material basis for science to grow. While all the rates have not been precisely the same, and as we shall see the recent doubling periods vary between about every 35 years (for population) and every four years (scientific expenditures, and the destructive radius of weapons), a neat identity would be too much to expect. The rapid growth in each of them is nevertheless closely interrelated and interdependent. As such they comprise a system in dynamic but stable equilibrium; change is interrelated in a highly dependable manner, and if we can for a moment forget the *rapidity* of change about us, looking backward over recent decades the highly “predictable” nature of that change is impressive. It has been like a rocket taking off from its launching pad—slowly gathering momentum until very great speeds are attained, but the acceleration has been quite steady and not at all fortuitous.

Yet *rigor* is only a part of the modern success story in prediction. The other major element is simply *information*, scads of it, precisely, in fact, one of the exponentially-growing phenomena being measured. Price’s statements about scientists are primarily inferences from the volume of scientific information; the most familiar set of data in his presentation refer to the number of scientific and technical journals, which has now reached over 100,000. Without this information explosion we would not know in a precise and detailed way, even to the degree necessary for fitting very rough exponential growth curves, about all the other changes. It has made possible the *inductive* generalization that marks so much current work in both sociology and political science. (Though many historians and political scientists have always held to a notion that “the facts speak for themselves.”)⁸ But large bodies of quantitative information are expensive and time-consuming to produce, and could never have been gathered by scholars working under nineteenth century conditions.

And curve-fitting is a tricky business. Formally speaking, many possible curves can be fitted to a single set of points.⁹ The “best”

⁸ This strain is exemplified by Henry Adams’ writings on American history, especially his *History of the United States of America* (London: Putnam, 1891-92, 9 vols.).

⁹ Arthur C. Clarke, *Profiles of the Future* (New York, Harper and Row,

curve is highly ambiguous, and if one has only a few observations, gathered perhaps for only a short period of time and subject to substantial error in measurement, the hazards are multiplied. With little data a straight line, an exponential growth rate, or even a cyclical pattern of hills and valleys superimposed on a rising trend may all be equally "correct" mathematically, and we may have little basis for preferring one or another. Even the fact of a rising trend may be misleading, especially as it may be related to a longer-term cycle. So the information-gathering side of things is crucial, and we need all the public and private data-gathering services in existence—at the same time that we need to devise means to prevent being snowed under in a blizzard of trivia.

Even rigor and information, the twin pillars of modern social wisdom, suffice only for limited tasks. The uncritical projection of exponential growth rates provides some of the worst examples of simple-minded curve-fitting. Quite obviously the world's rate of population increase will *not* continue unabated until the earth's density exceeds Hong Kong's; some kind of control, deliberate or natural, felicitous or disastrous, will prevent it.¹⁰ Still, the ease and attractions of simple projection have subverted many a would-be prophet. G. K. Chesterton, in his slightly pompous Victorian way, amply satirized the outlook:

When we see a pig in a litter larger than the other pigs, we know that by an unalterable law of the Inscrutable it will some day be larger than an elephant,—just as we know, when we see weeds and dandelions growing more and more thickly in a garden, that they must, in spite of all our efforts, grow taller than the chimney-pots and swallow the house from sight, so we know and reverently acknowledge, that when any power in human

1962), ch. 1 is a popular but sophisticated statement of this problem. He notes (p. 7) "Mathematics is only a tool, though an immensely powerful one. No equations, however impressive and complex, can arrive at the truth if the initial assumptions are incorrect."

¹⁰ Such a density would imply a total world population above 400 billion. Actually the upper limit to a population living "moderately well" is probably around 50 billion. One of the more buoyant pro-natalists (Colin Clark, "Agricultural Productivity in Relation to Population," in Gordon Wolstenholme, ed., *Man and His Future* (Boston, Little Brown, 1963), pp. 23-35), and one of the most creative minds working on the problem of how that population might be sustained (Richard L. Meier, *Science and Economic Development: New Patterns of Living* (Cambridge: M.I.T. Press, 1966, 2nd ed.), p. 147), seem to have arrived at this figure independently. Both describe the prospective living conditions in some detail; they might be characterized as appreciably better than those now prevailing in Latin America but probably inferior to—and certainly different from—those now typical of Europe.

politics has shown for any period of time any considerable activity, it will go on until it reaches the sky.¹¹

Some political and social predictions based on the extrapolation of apparent growth rates are only a little less absurd, yet even a sensible-appearing use may go very far wrong.¹² Upward trends do *not* go on forever, but at some point, for some reason, level off, oscillate, or go into a downturn. A child doubles in height between the ages of 2 and 18—but he won't (I trust) double his height again before he is 35. But political history is full of examples of failures to anticipate the system break, the turning point, when what used to be appropriate is no longer so. Generals' alleged preparedness to fight the last war is just such an instance. A national population policy which stressed producing large numbers was appropriate for an era when the number of soldiers a state could field was a major basis of its power; some countries, like Italy, carried that policy over into an age when per capita wealth was equally important as a power base. Political goals, as well as political methods, must be adapted to changes in the social and technological environment. Perhaps we have reached a period when the simple goal of maximizing the "national interest"—whatever that is—has become inappropriate in a world where heavy symbiosis and cooperation are unavoidable. We also must have sufficient discrimination to know which growth rates are important to us. By 1870 there was, within the British government, a clear awareness that Germany's growing steel production would intersect with Britain's before the end of the nineteenth century. For another decade, however, they thought that the country they had to worry about, for political reasons, was France, not Germany. Here then, are still a variety of crucial roles for imagination.

This is the kind of thing to which I want to devote the rest of this article: to examining some of the features of the environment of the international political system that have undergone very rapid

¹¹ G. K. Chesterton, *The Napoleon of Notting Hill* (London: John Lane, 1904), p. 19.

¹² One of the most forceful statements about the utility of prediction *via* extrapolating exponential growth curves is Hornell Hart, "Predicting Future Trends," (New York: Appleton-Century Crofts, 1957), pp. 455-73, and a good argument for caution, trying instead to anticipate jumps and quantum leaps, is Gardner Murphy, "Where is the Human Race Going?" in Richard E. Farson, ed., *Science and Human Affairs* (Palo Alto, Calif.: Science and Behavior Books, 1965), pp. 7-17. A more general treatment of how exponential growth rates change is Daniel Bell, "Twelve Modes of Prediction: A Preliminary Sorting of Approaches in the Social Sciences," *Daedalus*, 93, 3 (1964), pp. 845-80.

change in recent years, suggesting what the prospects are for their continued growth, and what their political consequences may be. There are at least four possible ways in which a smooth, continuous rate of growth in something may eventually have a discontinuous effect on other aspects of the system, producing what may be called step-level change or system transformation.¹³

Crossing a threshold

One is an increase which crosses a threshold, a rate of growth that continues until, on reacting with some other aspect of the social or political system, it produces a discrete change. A given equilibrium may be unstable. In forest ecology, forms of life, adapted to their environment, grow and develop in an area, but in so doing they modify their environment until it has changed so that they are no longer adapted to it. Hardwood trees, for instance, first become established in sunny, relatively open areas. But as they grow up and mature over many decades, they shade the ground beneath them, and in the shade young conifer trees thrive better than new hardwoods. In time, as the large hardwoods die out they are replaced by conifers, which in turn create even deeper shade that prevents the growth of any more hardwoods. The resulting "climax" forest is then in a static equilibrium, and will maintain itself indefinitely except for exogenous change introduced by the activities of man, fire, or other natural disaster. An obvious political example is the slow growth of a voting bloc that, on passing the 50 per cent mark, is able then to effect a sharp change in policy.¹⁴ Even here the change may not be all that discontinuous—some political change is likely to occur in response to the pressure of any large bloc, and some further change will arise in anticipation of its majority status as it approaches the half-way mark. But the principle, even though not entirely unambiguous in most empirical examples, is clear enough.

If in the future we have a world government, with effective authority over its member states or over individuals, this example might be of more importance for international politics than it now seems to be. Already the poor states (those with a per capita income of less than \$300 a year) form more than a majority in the

¹³ An early use of this approach in political science is, of course, Morton Kaplan's *System and Process in International Politics* (New York: Wiley, 1957).

¹⁴ Bertrand de Jouvenel, "Political Science and Prevision," *American Political Science Review*, 59, 1 (1965), p. 34.

United Nations, and actually they have the two-thirds majority which is required for issues defined as "important." If they were able to enforce their collective will they doubtless would expand United Nations assessments many times over, spreading the new revenues around for economic development. But though for years they have had the votes necessary to pass this assessment—and have been able to band together to defeat the rich powers on other occasions—they have not done so with the tax rate. It is one thing to assess taxes, quite another, in the current state of international organization, to collect them. So for the present they avoid a show of parliamentary strength that would merely expose their executive weakness.

Another example of this phenomenon which might have more immediate effect is provided by relative power relationships in the Middle East. Despite Israel's numerical inferiority to her neighbors (on the order of one to twenty) her wealth, organization, and external assistance, plus the divisions among the Arabs, allow her to remain militarily equal to her antagonists. But a sustained growth in income and organizational efficiency in Egypt could over the long run tip that balance in the Arabs' favor. The notion of a sharp system change or step-level jump is an over-simplification, but at least subjectively, if not objectively, Egypt could reach a point where its leader could decide that from then on he had the power to crush Israel. Whether he really was able to do it, whether he miscalculated and was beaten again, or whether Israel changed the whole threat system by going nuclear, the effect would nevertheless be of a slow and smooth change in one parameter that had, at some pretty clearly identifiable point, produced a discrete change in the system.

More generally, something of this sort has happened in the international system as a whole. Kenneth Boulding has adapted from economics what he calls the "loss of strength gradient," or the rate at which a nation's power declines with distance from its borders.¹⁵ For the major industrial powers this gradient has been steadily pushed outward since the Napoleonic Wars, as fewer and fewer states have remained "unconditionally viable." (He calls a nation unconditionally viable if it can prevent foreign imposition of a drastic change of political or social organization inside its own borders.) The ability of one nation to coerce another even at a great distance was strengthened first by social changes (such as the *levée*

¹⁵ Kenneth E. Boulding, *Conflict and Defense* (New York: Harper, 1960).

en masse, the aggregation of large nation-states, and revolutionary ideology), and then technological innovation (the steamship, tanks, aircraft, and finally the atomic bomb). For many years this meant that only six or so great powers were viable against any opponent, and that these great powers could conquer even far away small states.

The cumulative effect of these trends, however, produced a dramatic system-change at the end of World War II, when only the two superpowers could dependably resist the domination of any other state. The erosion of all other nations' unconditional viability is in effect what we mean by the transformation of the international system in the early postwar years.

And the bipolar system as we knew it only a decade ago has itself become transformed by the maintenance of the very same trends that first produced it. Continuing technological change, moving from atom bombs and manned bombers to thermonuclear weapons and intercontinental missiles, has removed the sanctuaries that the superpowers used to enjoy in their homelands. Thus there has been a limited revival in the independence of the middle powers, as the great powers can no longer provide such a credible deterrent umbrella. Yet though smaller states are not now so dependent on the big powers for protection—not dependent simply because they are not so confident in it—they still could never hope to *defeat* a superpower. Thus we are somewhere between a bipolar situation and a balance of power world with many foci of more or less equal strength.

Changes in transportation and destructive capacities produced fairly discontinuous changes in the political system, first by cutting the number of great powers to two, and then by restoring to those at the middle level *some* of the independence they had possessed before bipolarity. The elimination of *all* states from the “unconditionally viable” category makes the need for new political forms for the international system more pressing than ever. We hear less about this now than a few years ago when the balance of terror was thought to be unstable, but I think the passing of extreme bipolarity *increases* the long-run requirement for political change.

Possibly these trends will have further sharp effects on the international system. The most likely way would be if technology were for a while to favor strongly the defender, especially in the development of an anti-ballistic missile system for continental defense. Apparently such development has progressed a good bit farther than

most of us would have expected a couple of years ago, and an effective anti-ICBM defense no longer seems utterly out of the question for the two big and rich powers.¹⁶ If successful, and if not merely outflanked by chemical or bacteriological weapons, it would return its possessor to the unconditional viability of the good old days. But at the moment that still seems to be a long shot, and I suspect we must look in other directions for new ecological influences on the political system.

Demand and supply as limits to growth

The previous example was of a smooth trend that, on reacting with some other characteristics, produced a marked change in the system. There are in addition several possibilities for trends to stop moving along at their previously established rates—the growth stops, or at least is drastically modified. Our *second* class, then, is of a development that reaches a so-called “logical” ending point, where it stops because of a change in the needs, perception, and behavior of men, because the *demand* which initiated it has essentially been fulfilled. One such is probably in the destructiveness of modern weapons that I alluded to a moment ago. During the century preceding World War II the destructive radius of the biggest weapons then available grew at a doubling rate faster than every 10 years, with the perfection of explosive chemicals and the development first of large cannons and finally of blockbuster bombs. The explosion of the first atomic bomb marked a certain discontinuous jump here, and in the two decades following it the doubling period shortened, to about every four years, culminating in the 100 megaton weapon that can collapse an ordinary frame house within 30 miles of its explosion point. But there is an obvious limit to the destructiveness of modern weapons—the size of anything worth destroying. At the doubling rate of four years, another twenty would be quite sufficient for a weapon capable of obliterating an entire continent; less than a decade more would produce a doomsday machine with a destructive radius exceeding that of the globe. More than that would appear to be a waste of scarce resources. Weapons development and improvement might well continue, but along other dimensions like reliability, discrimination (as between men and structures in the neutron bomb), and “cleanliness.”¹⁷

¹⁶ See Jeremy J. Stone, *Containing the Arms Race* (Cambridge: M.I.T. Press, 1966), pp. 224–32, and Bruce M. Russett, “The Complexities of Ballistic Missile Defense,” *Yale Review*, Spring 1967.

¹⁷ The data in this and the following paragraph are from Bruce M. Russett, *Trends in World Politics* (New York: Macmillan, 1965), ch. 1.

Many of the characteristics of what has been termed the “mobiletic” revolution are likely also to fall into this category, and also rather soon. Mobiletics is a slightly inelegant but useful term coined to cover the whole range of movement—of things, of energy, and of information.¹⁸ One of its components is the transportation of men and other high value-per-unit-volume goods. In the nineteenth century the speed at which men could travel over transcontinental or intercontinental distances doubled more or less every 25 years. It began at the speed of the sailing ship or horse and carriage (depending on the medium), which was hardly more than five miles an hour over sustained distances in the early 1800’s. This progressed through the perfection of clippers, the steamship and the railroad. After the Wright brothers this rate speeded up, with a doubling about every ten years, reaching around 600 miles an hour in the late 1940’s and the 2000-mile-an-hour bomber in the early 1960’s. The built-in limits to the trend are fuzzy but fairly obvious, at least on this small earth. Something like a man-carrying intercontinental rocket is the top; 5000 mile missiles make the entire trip from point to point in under 30 minutes or roughly 10,000 miles per hour. Extrapolation of the 10-year doubling rate since the turn of the century would bring us to this limit sometime in the 1980’s. Since the 2000-mile-per-hour airliner is not expected to be operational until after 1970 this projection for the rocket seems rather over-optimistic, and the social demand for human travel at 10,000 miles per hour instead of 200 miles per hour is not likely to be so great as to require that the “schedule” imposed by extrapolating past changes be kept. In the longer run faster speeds for manned travel to the planets and beyond are to be expected, but even here the extrapolation to 30,000 miles per hour in the year 2000 is, give or take a few years and tens of thousands of miles, about as long as current rates of growth can go unabated. According to most scientific authorities, by then there would appear to be more payoffs in suspended animation, or interstellar travel by colonies that would reproduce themselves en route. The real upper limit to man’s travel capabilities may be only at the speed of light, but it is unlikely to be approached at the current high rates of increase. This, then, is another rate of change that will, within the lifetimes of some of us, slow down drastically.

¹⁸ Bertram E. Gross, *Space-Time and Post-Industrial Society* (Syracuse, N.Y.: Syracuse University, Maxwell School of Citizenship and Public Affairs, 1966, mimeo.), p. 4.

With the advent of the telegraph, communication became virtually instantaneous, at the speed of light plus processing time, over short distances. The changes are not so orderly that any simple exponential growth curve can be fitted to this one, but modern improvements have concentrated on eliminating the need for fixed channels of communication such as wires, on lengthening the distance that could be covered, and on providing facilities for transmitting a wider variety of messages, from electrical impulses that had to be translated from Morse code into letters, to impulses that could be made into faithful reproductions of sound and sight. When these developments culminate, as they will shortly, in the installation of a world-wide system of satellite relays to carry television impulses around the earth within two seconds, the most important dimension of the communication revolution will be completed.¹⁹ Further work will be left to clean up the quality and variety of transmission possibilities and to proliferate transmitters and receivers. These mobiletic changes, therefore, are now approaching their natural completion. Probably they will pick up again on some now hardly imaginable dimensions,²⁰ but it is unlikely that in the next fifty years or so they will again produce such a sudden change in the environment of international politics as they have just put us through.

These are growth rates that will slow down essentially as the *demand* is satisfied. Making an effective decision to speed up or slow down their growth is not always within the capabilities of our social and political systems, but at least the growth is not so autonomous that we need anticipate any particular difficulties when the "natural" slowdown points approach. This is by no means universally the case with rapidly growing social phenomena, so we are led to a *third* category—growth rates that come to a halt because the *supply* of some basic commodity is exhausted.

Behind all the changes just listed has been the explosion of science and technology. Since the eighteenth century the number of scientists in the world at large has doubled approximately every 15 years; in the United States alone the doubling rate has been faster, roughly every 10 years. This clearly can't go on. The number of scientists and engineers has now reached almost one per cent of

¹⁹ See John R. Platt, "The Step to Man," *Science*, 149 (August 6, 1965), p. 608.

²⁰ Sometimes this mutation and revival is called "escalation." See Gerald Holton, "Scientific Research and Scholarship: Notes Towards the Design of Proper Scales," *Daedalus*, 91, 2 (1962), pp. 369-99.

the total population,²¹ and if one eliminates the temperamentally and intellectually unfit (eliminates them only for analytical purposes), they amount to possibly one fifth of those who have the capacities to become productive scientists. Even if we forget about leaving high-IQ individuals for commerce, administration, and the arts, it is clear that this exponential growth curve has a built-in ceiling. We will see the end of it well before the century is out; it will affect our professional lives and especially those of our graduate students. Some mitigation may be in sight; for instance, utilizing the brain-drain of high-IQ people from underdeveloped countries, a reservoir that may not dry up for another fifty years or so; or extremely sophisticated computer usage; or hiring more secretaries; or improving information retrieval; or various ways of relieving scientists of the substantial drudgery that still remains in their work. Yet this kind of relief only postpones the day when surgery will be necessary. Federal obligations for research and development in the United States doubled roughly every four years between 1950 and 1964.²² But for the past three years they have levelled off at about three per cent of national income. This is nearly a third of what we now spend on defense, and even allowing for growth in real national income (perhaps a doubling every 20 years at an annual rate of about four per cent) it is hard to see how science spending can grow very much more. Depending upon how it is handled, the levelling-off of this trend could lead to a period of regrouping and digestion in science, as better means are perfected for making us aware of other people's research and avoiding some of the duplication that is currently so prevalent. In the world at large, it is conceivable that a levelling-off of the growth in science could slow down some of the more wasteful and dangerous aspects of international technological competition. In any case, the levelling has already begun.

The social control of growth

This leads us to a distinction which ushers in our *fourth* class of growth patterns—between growth rates that are brought to a halt *only* by resource limitations, and rates that are controlled, short of

²¹ This is from a projection and adaptation of figures for 1962-64 in U.S. Bureau of the Census, *Statistical Abstract of the United States, 1966* (Washington, D.C.: U.S. Government Printing Office, 1966), p. 547-48. I am assuming that the potential talent pool includes all those of working age with an IQ of at least 120.

²² *Ibid.*, p. 544, and *Statistical Abstract of the United States, 1959*, p. 539. The figures are not fully comparable, but the general pattern is unmistakable.

the physical limits, by deliberate social policy.²³ John Platt's fascinating essay on "The Step to Man" also mentions some of the growth curves I have detailed, and forecasts their orderly levelling-off.²⁴ But orderly transition may be the exception. A growth rate may reach its ceiling and, in the absence of social control or an escalation that picks up again on some other dimension, bump along the ceiling. In effect this is oscillation around the equilibrium level, and I will illustrate it with the outcome foreseen for the population explosion according to one model.

Imagine an island with no foreign trade and where there is neither emigration nor immigration—a closed system. The area of agricultural land is fixed, and for some time it has supported a population, growing at a constant rate, that has not yet required all of the available land. As land utilization reaches 100 per cent and the level of technology remains constant, the population will approach the maximum that the island can support. But if technology is evolving, as it has been in the Western world over the past several centuries, the ceiling may continually be pushed upward and the population may continue to grow at its exponential rate. Let us assume, however, that at some point the local farmers' ingenuity gives out and they exhaust all methods for substantially increasing the yield of their land. When this point is reached the population of the island will have attained its ceiling. Growth may not stop absolutely short in its tracks, for there may be some belt-tightening possible. But it must stop soon, and not necessarily as a simple levelling-off to a smooth plateau. On the contrary, after the first steps of belt-tightening the next consequence is likely to be a disease epidemic in a population made vulnerable by malnutrition, or there may occur a natural disaster which drastically cuts food production in a situation where there is no margin to spare. Instead of simply levelling-off, the population will drop

²³ I distinguish between this *planned diminution* and the simple relatively autonomous slackening of demand discussed as the second category. Note too that the first and third categories apply to environmental limitations that act regardless of human cognition, whereas the second and fourth operate only as a consequence of perceptions. This useful distinction between different environmental effects is made by Sprout and Sprout, *op. cit.*

²⁴ Platt, *op. cit.* An initially exponential curve that bends over smoothly in an S-shape is the logistic curve. An early example in demographic prediction is Lowell J. Reed, "Population Growth and Forecasts," *Annals of the American Academy of Political and Social Science*, 188 (November, 1936), pp. 159-66. The logistic curve may have looked applicable to U.S. population in the 1930's, but it does not fit later developments. The article is nevertheless useful as an explicit answer to the projection of exponential rates to infinity.

sharply in response to the sudden rise in death rates. But after this immediate disaster is past, there will again, at the advanced technological level achieved, be a surplus of land relative to population. So, for a short period, unless reproductive habits have been changed, the population will again shoot upward, at the previous rate, until the gap is filled once more. And again, the population will become vulnerable to disease or nature, will fall once again, and so on. Here is the classic Malthusian trap in which population is forced into equilibrium with limited productive resources. The pattern, however, is one of violent oscillations to and from a ceiling imposed by "nature."²⁵

Such a perpetual unhappy fate is nevertheless not the only possible denouement to the exponential growth curve. If, instead of allowing resource limitations to determine the situation, it is subjected to human volition and social control, a better solution is feasible. If the birth rate is brought down fairly quickly and made equal to the death rate before the ceiling is reached, the curve can be made to taper off smoothly and culminate in an even plateau without wild oscillation. Presumably there will be some fluctuation for a while, as the social controls are perfected and the right mix is found to depress the birth rate just to, and not beyond, the equilibrium level. But in principle the proper procedures could be worked out.

Going from the abstract model of the isolated island to the current world demographic situation brings, I would guess, substantial cause for optimism. Many sociologists and economists are more expert on demographic matters than I, and I will not try to encroach on their territory. It appears to me, however, that this represents a growth rate that is on the verge of being brought under control, at least sometime before the end of the century. I doubt very much that the world will look like our mythical island, or even like Hong Kong. For what is, by comparison with the funds expended for military research and development, a very modest investment, we have come up with a variety of extremely prom-

²⁵ A good example of thinking that hitting the ceiling is the only probable outcome to such demographic pressures is Sir Charles Darwin, "Forecasting the Future," in Edward Hitchings, Jr., *Frontiers in Science* (New York: Basic Books, 1958), pp. 100-116. Richard L. Meier, *Modern Science and the Human Fertility Problem* (New York: Wiley, 1959), pp. 53-63, forecasts something much like this happening in certain areas of the world, notably the island of Mauritius. For a similar result with a different mechanism (the stress syndrome) see Hudson Hoagland, "Mechanisms of Population Control," *Daedalus*, 93, 3 (1964), pp. 812-29.

ising methods for population control, and have still more in the works. Even a cosmic pessimist would have to admit that the technical side of this problem is being licked before our eyes. The social side—how to bring about widespread acceptance and use—is not so easy, but with the new attitudes in developed and underdeveloped countries alike, it does not seem so formidable as it did only a few years ago. I should perhaps say these things in a still small voice, since I am assuming a high degree of public awareness and determination to defeat the threat, a degree that has not yet been reached and must be maintained for decades if my prediction is to come true. It could, if it makes us complacent, become a self-defeating prophecy. And I am aware that the details of solving this problem could yet be very difficult, and that the quality of life on earth may well depend less on *whether* the demographic revolution is brought to its thermidor, than on how quickly. A delay of a generation will mean almost twice as many people to accommodate, and give us some very serious economic and political crises throughout Asia—crises that may be partly avoided by more rapid action. Thus I am very much in sympathy with those who are in a hurry. But this is nevertheless a promising area. With some luck, determination, and dedication, it may become an example of how a social pattern, an exponential growth rate of enormous import, was brought under control before it reached its built-in ceiling and burdened mankind with its oscillations.

Here then is a prediction, imbued with I think only a small component of over-optimism, for the turn of the coming century. The population explosion will be, at least for macro-purposes, ended. We may not have reached the state of equal birth and death rates and hence a stable population, but the rate of growth should be much reduced. The world food crisis will have been met and surmounted. (Notice, however, that I did *not* say avoided. I do not think we will get off that easily. Before population control takes full effect we will have had to deal with mass famine in Asia.) The problem of economic development will still be with us, and perhaps in even more pressing form. But it will be in *different* form, for rapid population growth will no longer be a major brake on the developmental process, demanding heavy inputs of capital investment just to stay in place. The major problems instead will be in the areas of organization, determination, and the difficulties of controlling the social and political unrest that is associated with the middle stages of economic development. How to cope with rising

expectations, with wants that increase even faster than growing satisfactions, will not be an easy question. The last stages of the mobiletic revolution, in bringing to even the poorest members of world society images of how foreign and domestic rich live, will enormously exacerbate problems we can already see.

The end of stable change

For the past century men in the Western world, and more recently over the rest of the globe, have lived in a period when change was the usual state of affairs. Though the change has been exciting, disruptive, and demanding for the individuals undergoing it, all of us have become accustomed to it; our parents with some head shaking, our children in a way that takes space travel and other wonders in stride as normal and utterly expectable events. Prediction of the ecology of international politics has been difficult primarily because for most of the time we have been so ignorant about the precise magnitudes of change and its predictable regularities. Had we before us accurate information about past experience, and courage enough to extrapolate, much of the present situation could have been predicted merely by expecting more of the same that had prevailed—not the same levels, but the same change rates. Relatively speaking, *political* prediction would have been easy (given today's data sources and theoretical achievements). Persistence forecasting, or the extrapolation of mildly sloping trends, would have been accurate. But until recently much of the necessary quantitative information simply had not been assembled, and since one can hardly extrapolate a trend without knowing what the trend is, we have a clear example of a case where neither imagination nor rigor were, by themselves, sufficient for adequate forecasting. Where precise data are still lacking, the normal difficulties of forecasting have been compounded recently by the rapid changes implied in the high levels now reached on many of the exponential growth curves, where a doubling in eight years instead of twelve can make a very great difference in the absolute changes with which society must cope.

Some of these problems will remain in future years, but as more and better data become available, and as social science develops greater rigor and a better understanding of our environment, they are being eased. For a brief period prediction may have great success in a world of rapid but dependable change. It will soon be shaken, however, by the system breaks that can be discerned in

the not so distant future. Then new qualities of imagination will be required, both to *predict* and to *determine* what the world will be like. Much of the future will depend upon which growth rates change first, and whether by orderly deliberate control that brings them to a plateau with a minimum of oscillation, or whether they bump up and down against a ceiling imposed by the environment. Doubtless we all would prefer a world where population growth was brought to a regulated halt, rather than one where Malthus reigned supreme and the population rose and fell with epidemics and bad harvests. And because many of these growth rates *are* interrelated, an uncontrolled change in one is likely to have far-ranging effects.

For several generations we have been living in an era of transition between great system changes. That era is now coming to a close, and a period of instability is ahead. We have a limited amount of time to break loose from habit, inertia, and administrative routine, to decide which trends we most need to control, and to devise ways of doing it. Without adopting a naive eighteenth-century faith in the omnipotence of science, it is nonetheless true that when a social need is strongly felt *some* solution is often found, even though no one could have predicted in advance precisely what that solution would be.²⁶ On the whole, I am hopeful that the necessary social and technological innovations can be found under pressure, although the time is short and the margin for error not at all wide. The population control experience is a good omen here. Only ten years ago one could not have said which, if any, of the possibilities then being explored might pay off; now we find unanticipated degrees of freedom. Maybe something of the sort will arise for international politics and world order. Right now no one can produce a scheme for the year 2000 that really looks workable, but as the pressure comes on, ingenious men may be able to develop something.

While trying to improve our predictive powers we must, at the same time, avoid *depending* on a high level of predictive success. We must maintain a pluralist approach so as to be able to adapt to the unexpected; we must have several possible alternatives and

²⁶ See Bell, *op. cit.*, and John R. Platt, *The Excitement of Science* (Boston: Houghton Mifflin, 1962), ch. 4, for good discussion of how this may be true, and also L. B. Slobodkin, "On the Present Incompleteness of Mathematical Ecology," *American Scientist*, 53, 3 (1965), pp. 347-59. It is important, however, to distinguish between what an *observer* might diagnose as social needs, and effective social *demands*.

“keep our options open.” It is worth recalling a statement by Alfred North Whitehead that is even more appropriate now than when he wrote it forty years ago:

We must expect that the future will be dangerous. It is the business of the future to be dangerous, and it is among the merits of science that it equips the future for its duties. . . . The middle class pessimism over the future of the world comes from a confusion between civilization and security. In the immediate future there will be less security than in the immediate past, less stability. . . . There is a degree of instability which is inconsistent with civilization. But, on the whole, the great ages have been unstable ages.²⁷

²⁷ Alfred North Whitehead, *Science and the Modern World* (New York: Macmillan, 1925), p. 291.